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Aircraft Measurements for Understanding Air-Sea Coupling and Improving Coupled Model Predictions Over the Indian Ocean

PI: Shuyi S. Chen

RSMAS/University of Miami
4600 Rickenbacker Causeway, Miami, FL 33149
Email: schen@rsmas.miami.edu

LONG-TERM GOALS

The goals of this PI are to understand the physical processes that control the air-sea interaction and its impact on a wide range of weather and climate systems and improve coupled atmosphere-ocean prediction through development of innovative coupled models and observations.

OBJECTIVES

The specific objectives of this study are to

- obtain coincident measurements of the lower atmosphere, air-sea interface, and the upper ocean adequate for coupled model evaluation;
- better understand the physics of air-sea coupling and its impact on convective organization including convectively induced cold pool structure;
- examine corresponding air-sea fluxes and boundary layer recovery that affects time scales of convection;
- diagnose high-resolution coupled model such as COAMPS forecasts of convective cloud systems and convective cold pool structure to determine the effects of air-sea coupling on the convective organization in the coupled model on diurnal, 2-day, and synoptic variability and their up-scaling influence in both convectively active and suppressed phases of MJO; and
- improve physical representation of the air-sea coupling processes in coupled models through airborne and satellite observations over the Indian Ocean.

The outcome of this study is expected to improve MJO prediction through a better understanding of the physical processes and a unique data set for model evaluation, verification, and potential for coupled data assimilation, which are critical for developing a new generation, high-resolution, coupled models.

APPROACH AND WORK PLAN

The air-sea measurements obtained using the NOAA WP-3D aircraft during the DYNAMO/LASP (Dynamics of Madden-Julian Oscillation/Littoral Air-Sea Program) field

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campaign from November-December 2011 will be used to address science questions related to “air-sea interaction and its impact on cloud processes in MJO.” Our approach is to make aircraft measurements with flight patterns designed to address various issues on convective and air-sea coupled processes and coupled modeling. The observations collected during the field campaign will be followed by in-depth data analyses. The aircraft measurements will complement ship measurements by providing an extended coverage of the high-resolution fixed-point time series obtained from a ship. The observations will be used to evaluate the performance of high-resolution, coupled model such as COAMPS to identify error sources and guide further improvements in representing the physics of the coupling processes on various time and spatial scales.

WORK COMPLETED

Research supported under the current LASP grant has been conducted in three phases during FY11-12. Here is a brief summary:

1. Pre-field campaign: January-October 2011

- Satellite data analysis for aircraft mission planning (METEOSAT-7 cloud cluster tracking, ECMWF analysis fields, University of Miami website in realtime: http://orca.rsmas.miami/~eryan/ConvTracking/dyn_index)

2. Field campaign: November-December 2011

- Daily weather forecasts and briefing for aircraft operations in Diego Garcia, reports posted on EOL field catalog in realtime (<http://catalog.eol.ucar.edu/cgi-bin/dynamo/report/index>);
- Dropsonde data processing on all P3 flights and realtime QC/reporting to GTS; and
- Science summary of aircraft missions posted on EOL website (<http://catalog.eol.ucar.edu/cgi-bin/dynamo/report/index>)

3. Post-field campaign (including on-going data analysis into FY13):

- Dropsonde data analysis, worked with EOL on data quality control (QC), participated in the DYNAMO Sounding Workshop at EOL/NCAR from 6-7 February 2012;
- Working in collaboration with Dave Jorgensen on Doppler radar data analysis for convective missions;
- Working with NCAR/UW S-PolKa PIs and Chris Zappa on fresh water pools/SST variability, and tropospheric water vapor profile comparisons;
- P3 and Falcon aircraft data intercomparison, participated in the DYNAMO Radar Workshop in Seattle from 23-24 August 2012
- Working with aircraft and ship groups on air-sea fluxes, cold pools structure and recovery
- Participating in model intercomparison group including COAMPS
- Preparation for publications of research results on 1) dry air intrusion and its impact on ITCZ-MJO interaction (Chen et al. 2012a), and 2) convective cold pool structure and recovery in MJO (Chen et al. 2012b).

RESULTS

1. Daily weather reports

To support the DYNAMO/LASP aircraft operation in Diego Garcia, we have provided daily weather forecast and briefing material for the science team and aircraft crew. An example of the daily weather forecast is shown in Fig. 1. These daily reports are posted and archived at the DYNAMO field catalog at <http://catalog.eol.ucar.edu/cgi-bin/dynamo/report/index>. They will facilitate the post-field campaign data analysis for all DYNAMO/LASP investigators and a broad research community. Furthermore, the real-time model forecasts will be evaluated and verified using the field observations.

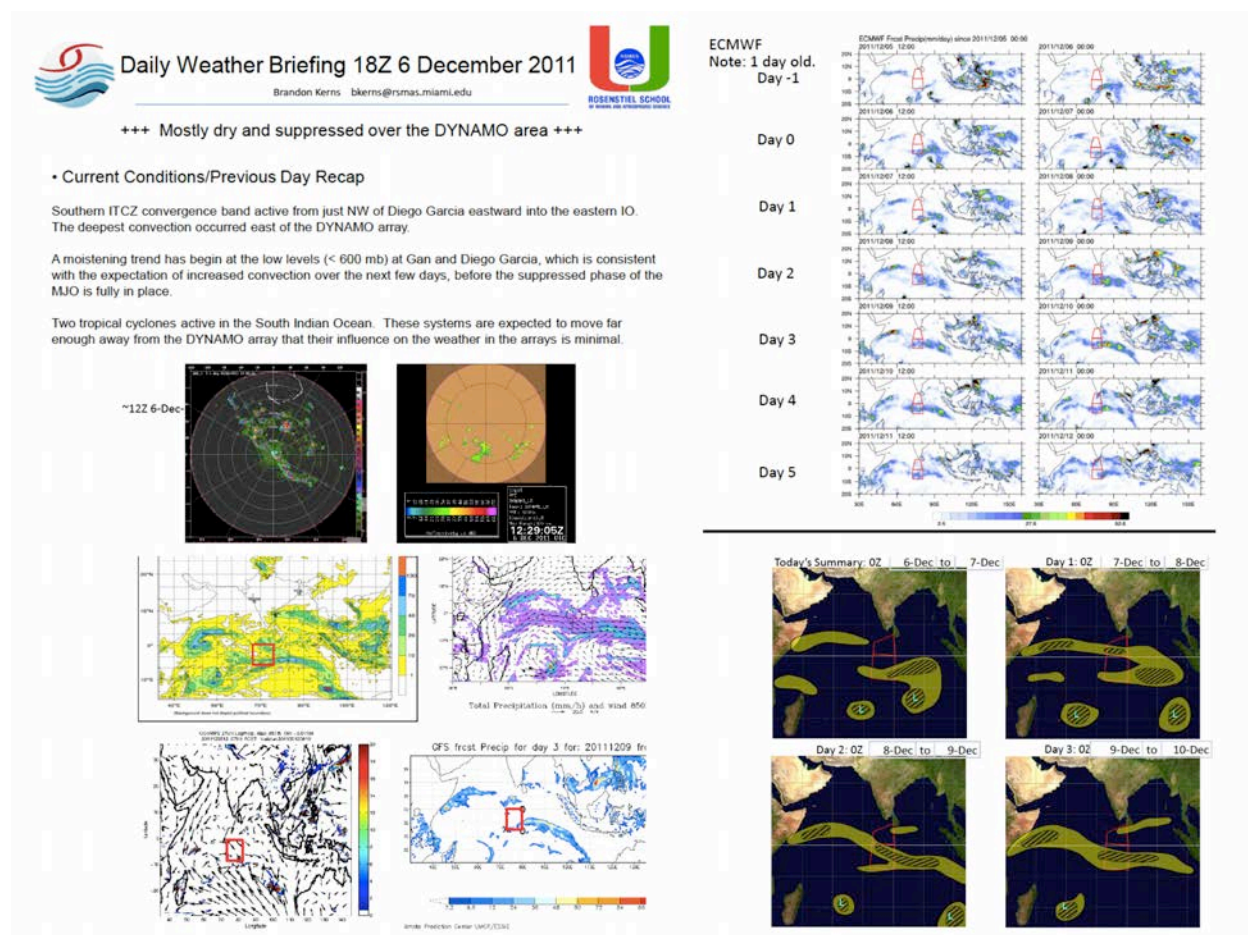


Fig. 1 University of Miami daily weather forecasts/reports during DYNAMO (available at .

2. NOAA P3 aircraft observations and science summaries

The aircraft missions are designed to sample the MJO initiation event from the convectively suppressed phase to active phase (Fig. 2). The convective cloud clusters shown in Fig. 2 are derived from the hourly METEOSAT-7 IR data based on Chen et al. (1996). The corresponding surface observations show a pre-convective onset period of the MJO initiation

with mostly rain-free and relatively isolated convective events captured by the surface rainfall and a warm trend in the SST data, which is followed by a more continuous heavy rainfall that marks the onset of organized convection in the MJO initiation. Figure 3 shows a summary of the NOAA WP-3D flights during DYNAMO. The PI (Chen) has written detailed mission science summaries, which have been posted and archived at the DYNAMO Field Catalog (<http://catalog.eol.ucar.edu/cgi-bin/dynamo/report/index>).

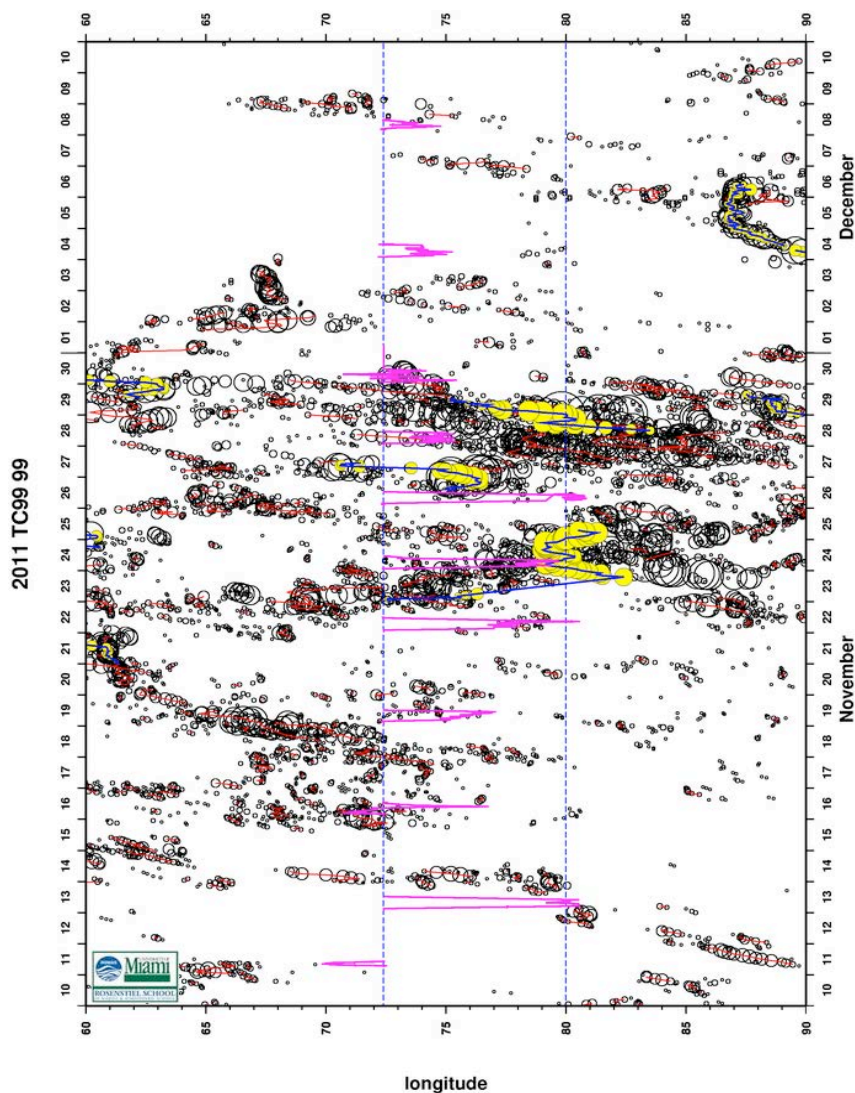


Fig. 2. Time-longitude plot of cloud clusters ($T_b < 208$ K) from 10 November-10 December 2011. The clusters are within the tropical latitude zone between 10°S - 5°N . The size of black circles is proportional to the size of observed cloud clusters. The DYNAMO observing array is within the region between the blue lines (~ 72 - 80°E). The NOAA WP-3D aircraft flight tracks are in magenta.

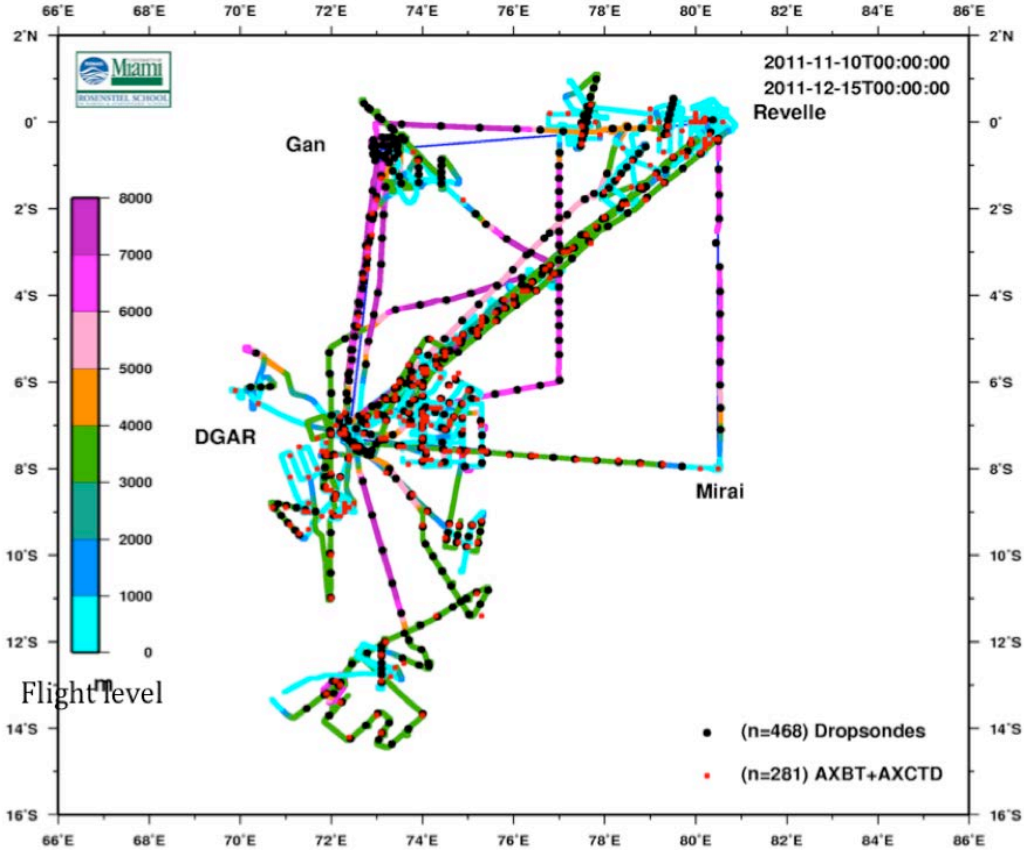


Fig. 3 Summary of the NOAA WP-3D aircraft flight tracks from the ten science missions from 13 November-8 December 2011, a test flight on 11 November and a calibration flight on 13 December. The height of flight level is indicated by the color bar. The air-deployed GPS dropsonde and AXBT locations are indicated by the black and red dots, respectively.

3. Convective cold pools and boundary layer recovery

To characterize the convective cloud systems and their impact on the air-sea interface, we use the aircraft data to investigate both the convectively generated cold pool structure and boundary layer recovery time during convectively active and suppressed phases of MJO. The P3 Doppler radar data is first used to identify the convective cloud and precipitation structures. The dropsonde data are used to compute the negative bouncy depth. The boundary layer recovery time is then calculated based on the method used in TOGA COARE (Jorgensen et al. 1997). The air-sea fluxes are computed from the dropsonde and AXBT data. Preliminary results show that the depth of the cold pools is related to the environmental water vapor (700-500 hPa layer mean) and the boundary layer recovery times are positively correlated with the surface wind speed and air-sea fluxes (Fig. 4). The drier environment during the suppressed phase seems to produce deeper cold pools and slower recovery time. Stronger winds and increased air-sea fluxes reduce the recovery time during the convectively active phase, which indicate a positive feedback between the convection and air-sea fluxes.

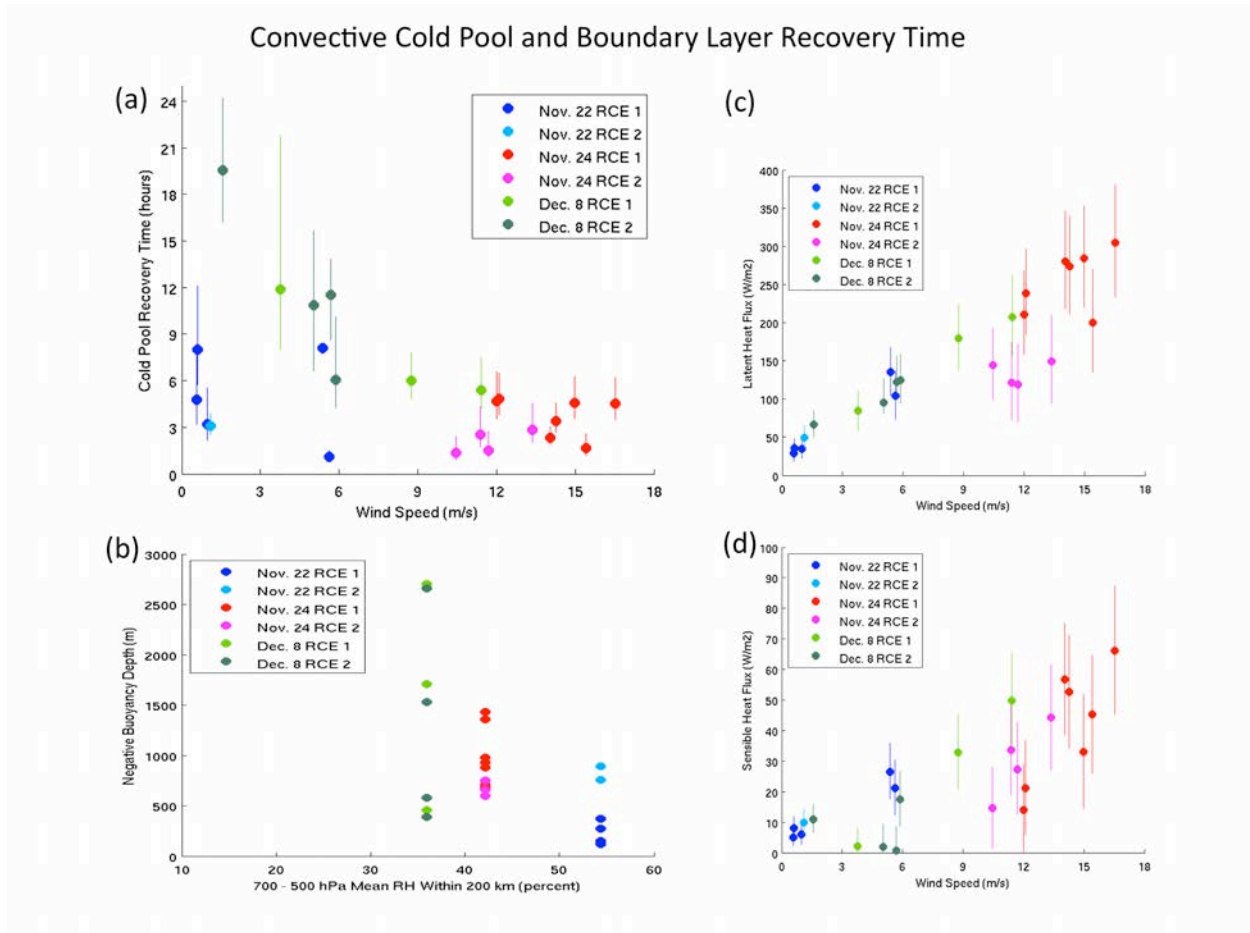


Fig. 4 Convectively generated cold pools and boundary layer recovery times are computed from convective flight modules (RCEs) during MJO transition phase (Nov 22, 2011), convective active phase (Nov 24), and convectively suppressed phase (Dec 8): (a) boundary layer recovery time varying with wind speed, (b) cold pool (negative buoyancy) depth varying with 700-500 hPa mean RH, (c) latent and (d) sensible heat fluxes varying with wind speed. The vertical bars represent uncertainty using ± 1.0 °C in SST variations.

FY13 WORK PLAN

The UM group will complete the following tasks: 1) satellite and aircraft data analysis of convective cloud systems, cold pool structure in relation to tropospheric moisture, and air-sea fluxes in convectively active and suppressed phases, 2) summarizing the science results in peer reviewed publications, and 3) working with NRL COAMPS team to process and analyze the COAMPS model output in the same way as the DYNAMO observations.

PUBLICATIONS (in preparation)

- Chen, S. S., B. W. Kerns, D. P. Jorgensen, F. Judt, C.-Y. Lee, C. Zappa, S. Brown, J. Delanoe, and N. Viltard, 2013: Overview of aircraft observations in DYNAMO/LASP: Emerging science in MJO, *BAMS*, in preparation.
- Chen, S. S., B. W. Berns, A. Saravin, F. Judt, C.-Y. Lee, D. P. Jorgensen, 2013: Convectively induced cold pool structure and boundary recovery in DYNAMO using airborne observations, *J. Atmos. Sci.*, in preparation.

CONFERENCE PRESENTATIONS

- Chen, S. S., C.-Y. Lee, F. Judt, B. W. Kerns, E. Ryan, and D. P. Jorgensen, 2012a: [Spatial Variability of Tropospheric Water Vapor and Convective Cloud Systems in DYNAMO](https://ams.confex.com/ams/30Hurricane/webprogram/Paper206141.html) (<https://ams.confex.com/ams/30Hurricane/webprogram/Paper206141.html>), AMS [30th Conference on Hurricanes and Tropical Meteorology](#), 15-20 April 2012, Ponte Vedra Beach, Florida
- Chen, S. S., B. W. Kerns, C.-Y. Lee, F. Judt, E. Ryan, D. P. Jorgensen, 2012b: [Coupled Observations and Convectively Induced Air-Sea Interaction in DYNAMO](https://ams.confex.com/ams/20BLT18AirSea/webprogram/Paper209945.html) (<https://ams.confex.com/ams/20BLT18AirSea/webprogram/Paper209945.html>), AMS [20th Symposium on Boundary Layers and Turbulence/18th Conference on Air-Sea Interaction](#), 9-13 July 2012, Boston, MA
- Jorgensen, D. P., S. S. Chen, and Q. Wang, 2012: [DYNAMO Convective Systems – Insights from Data Provided by the NOAA P-3 Aircraft](#), AMS [30th Conference on Hurricanes and Tropical Meteorology](#), 15-20 April 2012, Ponte Vedra Beach, Florida